**Proceedings of the Institute of Acoustics**

# ACOUSTIC CHARACTERISTICS OF THERMO-BONDED FIBRES

J. Redondo Politechnical University of Valencia, Gandia, Valencia, Spain
J. Ramis Politechnical University of Valencia, Gandia, Valencia, Spain
J. Alba Politechnical University of Valencia, Gandia, Valencia, Spain
J. Venero Politechnical University of Valencia, Gandia, Valencia, Spain
V. Sanchis Technical Manager, PIEL,S.A. Pol. Ind. Casa Felisio, Agullent (Valencia )Spain

## 1 INTRODUCTION

In this work we present experimental measurements of impedance and absorption coefficient of thermo-bonded fibres (TBF) manufactured by the Spanish company Piel S.A., in order to evaluate the applications of this material in the field of room acoustics. The tested samples have been TBF of different densities and thickness. We also compare the results with the well-known ones for mineral wool. The absorbent characteristics of the tested materials show that they can be appropriate for the use in acoustic conditioning.

## 2 AIMS OF THE WORK

Since the beginning of room acoustic lots of different materials have been used to control the reverberation in enclosures and to decrease the sound transmission though walls. However, in last years, some other applications have appeared like to reduce noise in aircraft, automobiles, factories and roadway construction. Fibreglass, Kevlar, ceramic wool, some metallic honeycomb structures, and the most extended, mineral wool, have a fundamental disadvantage. All of these materials are produced in pre-shaped forms and usually they are difficult to cut in different sizes.

As it is well known, porous materials are typical in acoustic conditioning and noise control. On the one hand, when used alone they are effective absorbers of medium and high frequencies and, on the other hand, they increase the range of effectiveness of the resonators either in membrane resonators or in cavity resonators. The sound absorbent capacity of this kind of materials can be determined from two types of measurements, the impedance tube and the reverberant chamber.

The aim of this work, promoted by the Spanish company Piel, S:A., is to prove that TBF are an alternative acoustic conditioning as substitute of mineral wool materials. For that purpose we have measured the acoustic impedance, the acoustic flow resistance and the absorption coefficient of different TBF. The materials tested are three different commercial TBFs used for sofas, painting brushes, and so on. The aim for testing these materials is due to its relatively low cost and another advantage with regard to other materials, their cutting and manipulation result really easy and safe for workers.

The sound frequencies with interest in this field are those between 100 Hz and 5000 Hz according to the standard ISO 354/85[1]. Due to that we present measurements of the absorption coefficient of porous materials in the frequency range mentioned. However, due to limitations of the techniques used to measure the impedance and flow resistance, the results for that magnitudes will be presented in a different frequency range.

# 3 EXPERIMENTAL APPARATUS AND RESULTS

The characteristics (thickness and densities) of the TBF tested samples are shown in the table 1. It must be pointed out that the compaction degree is different among the samples.

| | Density (g/m$^2$) | Thickness (cm) |
|---|---|---|
| 1 ( light TBF) | 250 | 4 |
| 2 ( intermediate TBF) | 500 | 5,5 |
| 3 (heavy TBF) | 800 | 7 |

Table 1: Characteristics of the tested materials

## 3.1 Impedance Tube

As a starting point we have measure the acoustic impedance[4] of the samples. The acoustic flow resistance has been measured as well. Figure 1 shows the noncommercial impedance tube used for that purpose. Figure 2 shows the results for impedance and normal incidence absorption. It can be said that the acoustic impedance of TBFs is slightly larger than the mineral wool one. This causes that the acoustic absorption is smaller for TBFs.

Figure 1 Non-commercial Impedance tube made of Perspex

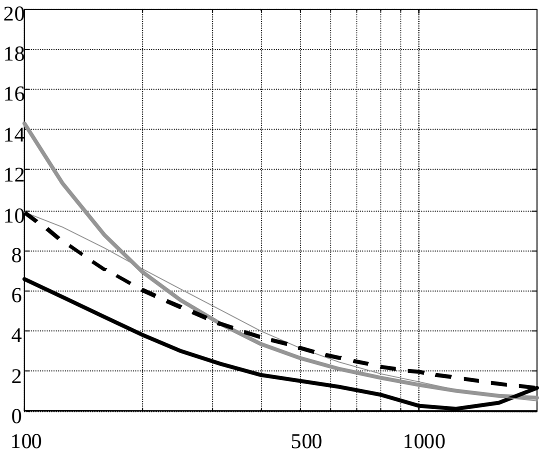


Figure 2a.- Normalized Acoustic Impedance of the tested materials vs frequency (Hz)

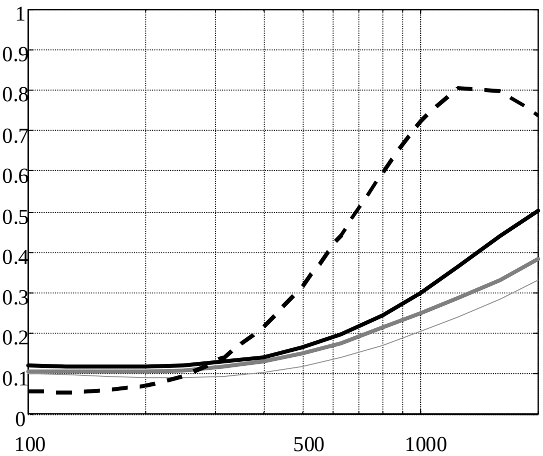


Figure 2b.- Absorption coefficient of the tested materials versus frequency (Hz).

Thin line, 250 gr/m2 TBF. Light grey line, 500 gr/m2 TBF. Dark grey line, 800 gr/m2 TBF. Dashed line, standard mineral wool.

Figure 3 shows the results of the measurements of the acoustic flow. As it can be seen the acoustic flow resistance of the TBF is substantially smaller than the one for mineral wool. These facts seem to indicate that they are not appropriate, for acoustic isolation. However, the measurements of impedance presented in figure 2, show interesting results. One can guess that if these materials are used in multilayer partitions, they can provide large changes in impedance increasing the final isolation.

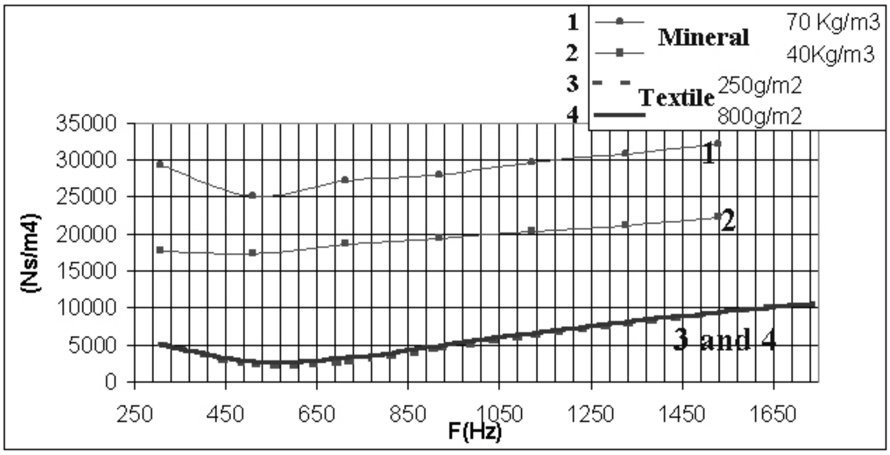


Figure 3.- Acoustic Flow Resistance of estándar mineral wools and TBF (textile).

## 3.2 Sound absorption coefficient measurements in Reverberant chamber

More than forty different configurations have been tested in our reverberant chamber following the ISO 354 norm and the UNE-EN 20354. Results can be checked in figures 4a to 4f. In all the figures the legend is the following: Dotted line, configuration without material. Thin line, 250 gr/m2 TBF. Light gray line, 500 gr/m2 TBF. Dark gray line, 800 gr/m2 TBF. Black pointed line (when available) standard mineral wool (70 Kg/$m^3$). Black dashed line (when available) configuration without TBF or mineral wool.

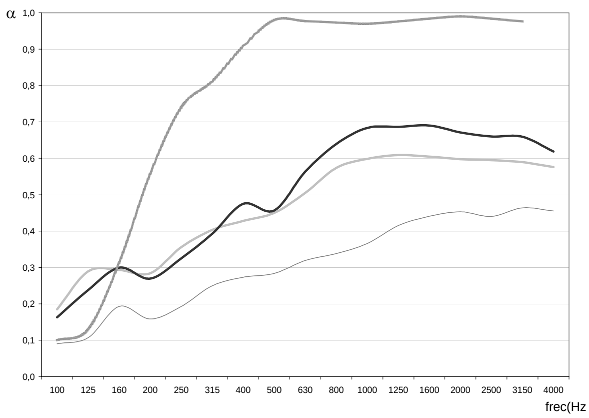


Figure 4-a.- Just TBF. From an acoustic standpoint it can be derived that the TBF behaves as a porous material. The influence of the thickness is also clear and also corresponds to the typical of porous materials. We can observe that exists a displacement of the maximum of absorption towards low frequency with the increase of the thickness. Another conclusion than can be obtained is that it is not useful to increase the density over 500 gr/m2. In general the absorption provided is substantially smaller that the one provided by mineral wool.

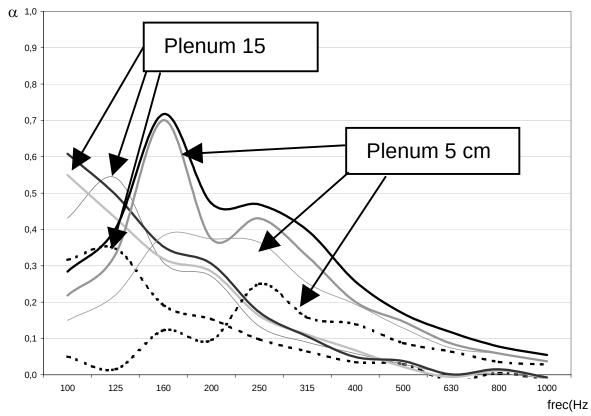


Figure 4.b.- Membrane resonators. Frames (see figure 5) stuff with TBF were covered with flat wood panels (thickness 6 mm). The inclusion of the TBFs in the configurations, increases the effectiveness of the resonators, and extends the frequency range of absorption.

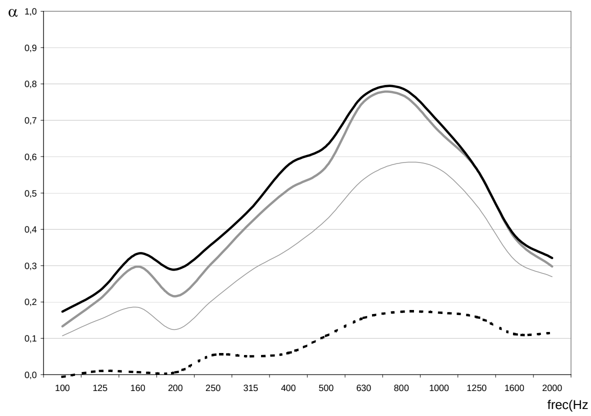


Figure 4.c.- Multy-cavity resonators (perforated panels) (plenum 5 cm). Frames (see figure 5) stuff with TBF were covered with wood panels with circular perforations. The inclusion of the TBFs in the configurations, increases the effectiveness of the resonators, and extends the frequency range of absorption.

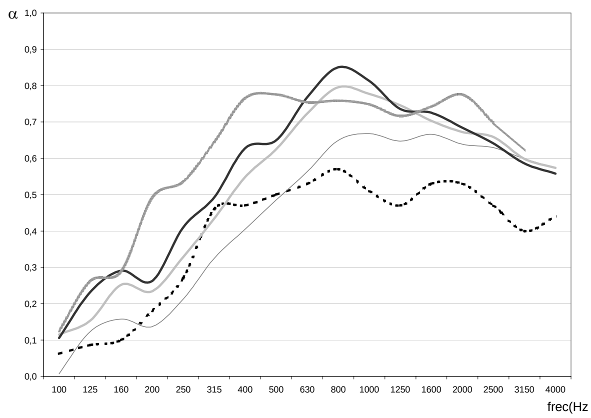


Fig 4.d.- Thick permeable cloth. Frames (see figure 5) covered with a thick textile material acoustically permeable

It can be said that the results for the TBF do not differ too much to the ones obtained for the mineral wool.

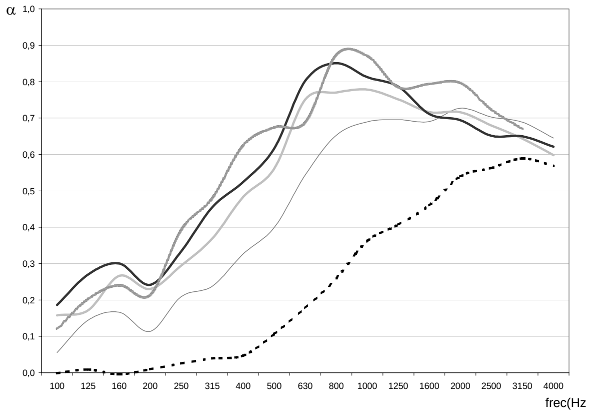


Fig 4.e.- Thin permeable cloth. Frames (see figure 5) covered with a thick textile material acoustically permeable

It can be said that the results for the TBF do not differ too much to the ones obtained for the mineral wool. In this case the increase of effectiveness is larger than in the case of thick cloth.

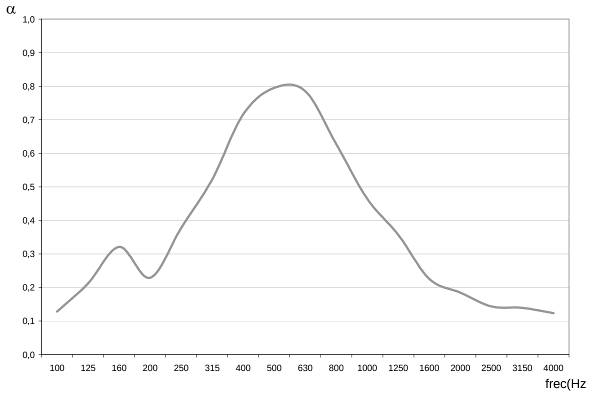


Fig 4.f.- Impermeable cloth. The TBF covered with an impermeable material behaves like a resonator (See figures 4-b and 4-c).

Fig 5.- Photograph of the frame used for different configurations tested in the reverberant chamber. (See text)

## 3.3 On the representation of uncertainty

It can be easily demonstrated that the main sources of uncertainty in absorption coefficients are the uncertainties in the reverberation times measured without and with sample. It is wellknown[5] that the uncertainties on the reverberation times are greater at low frequencies and when the sound absorption coefficient of the test specimen is high because the sound filed diffusivity is smaller in that cases.

In previous sections we have shown some results that cover almost all the range of variation of the absorption coefficient for all the frequency bands of interest. This has motivated us to perform a numerical evaluation of the influence of the sound absorption of the sample on the uncertainty of the absorption coefficient. Figure 6 illustrates the dependence of the absolute uncertainty with the absorption coefficient at third octave frequency bands. It can be seen that the experimental results are near to a linear behavior.

In fact there is another magnitude that must be considered: the scattering coefficient of the tested material. However all of the samples considered in the present work are almost plane so the scattering provided by the sample can be neglected.

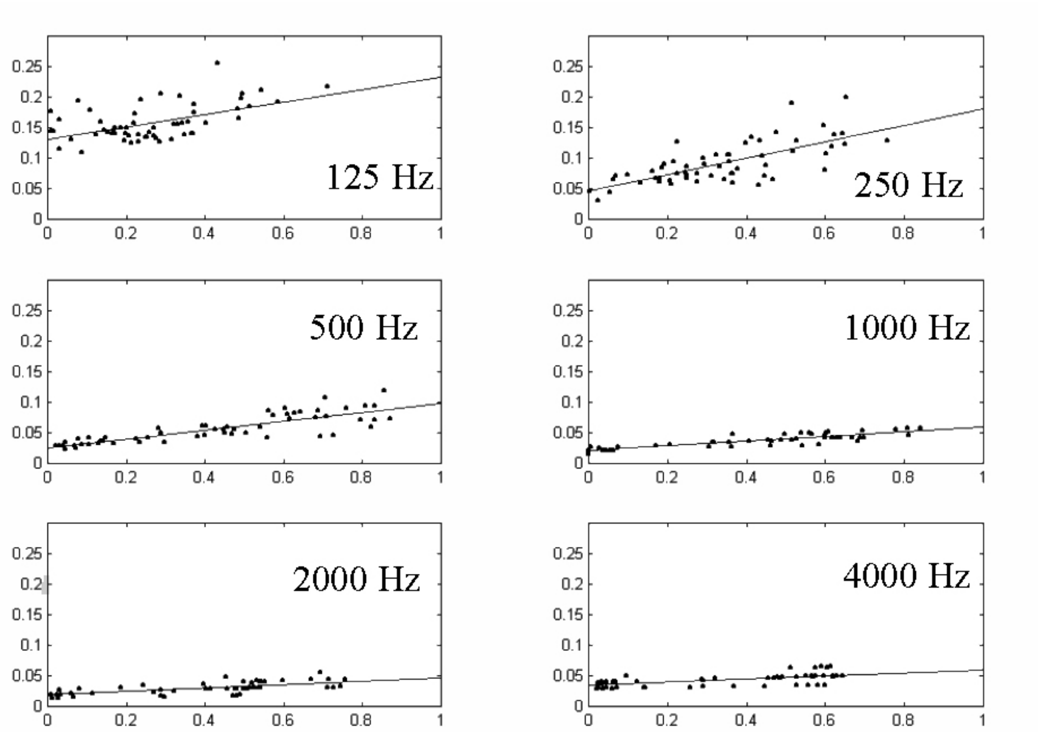


Figure 6 Uncertainty (standard deviation) in the absorption coefficient versus absorption coefficient of the test sample at different frequencies.

As expected the uncertainty in the measurements is greater at low frequencies and when the sound absorption coefficient of the test specimen is high.

The relation between uncertainty, absorption coefficient and frequency can be easier visualized in a contour or density plot that also can improve the graphical representation of the uncertainty when some similar materials are shown conjointly. Figures 7 a, b and c illustrates different possibilities of representing the uncertainty associated to figure 4a. In figure 7 a, the typical error bar technique has been used. In the zones where the differences between the plotted curves are small it is difficult to follow them. Figure 7b corresponds to the same curves but plotted over a density plot proportional to the uncertainty. It is easier to visualize all the information that is available, i.e. the magnitude and its uncertainty. If the curve is difficult to see over the density plot it means that the uncertainty is to high, and on the contrary, if the curve is easy to distinguish the uncertainty is small.

Figure 7 c is the same but with a density plot proportional to the relative uncertainty. This is an additional advantage of such a kind of representations. It is unusual to find graphical representations of physical magnitudes including the relative uncertainty. It is important to keep in mind that relative uncertainty gives us an idea of the uncertainty in any magnitude related with the absorption coefficient by a formula, by instance the reverberation time of a room in which the tested material was used.

An interesting property of the density plots is that they can be used as plot templates for future measurements that could be carried out in our reverberant chamber. However the density plots are valid only in the case of measuring flat surfaces, i.e., with small scattering coefficients.

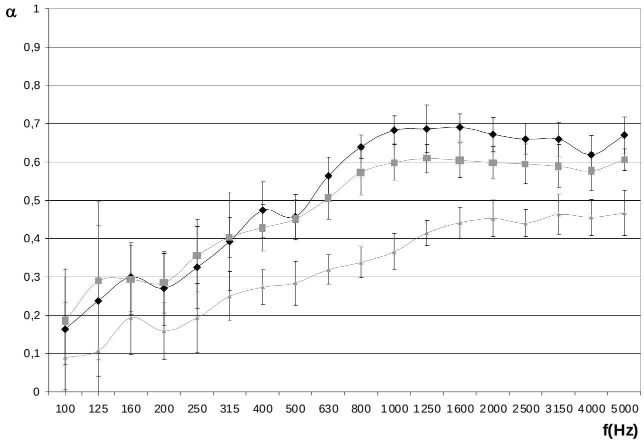


Figure 7 a. Error bars plot version of figure 4 a.

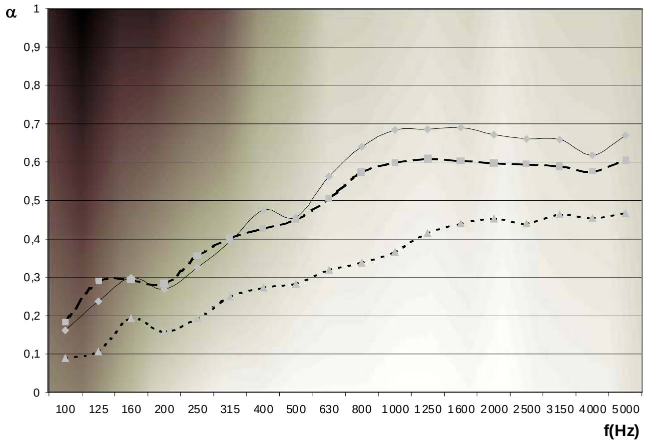


Figure 7 b. Lines over a density plot proportional to the absolute uncertainty of the measurements. (Dotted line, 250 gr/m2 TBF. Dashed line, 500 gr/m2 TBF. Continuous line, 800 gr/m2 TBF.).

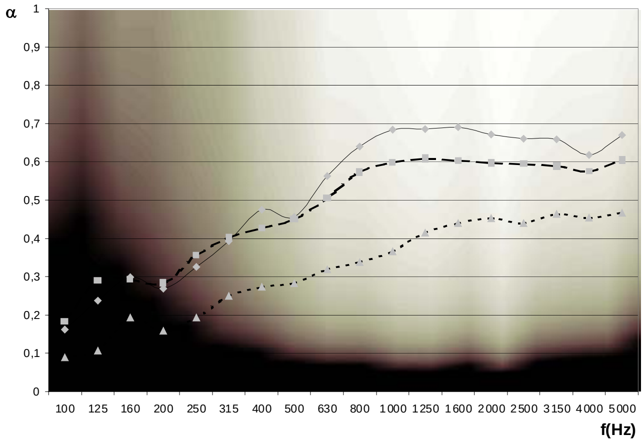


Figure 7 c. Lines over a density plot proportional to the relative uncertainty of the measurements. (Dotted line, 250 gr/m2 TBF. Dashed line, 500 gr/m2 TBF. Continuous line, 800 gr/m2 TBF.).

# 4 CONCLUSIONS

On sight of the obtained results, the TBF provides a wide variety of acoustic behaviors that can be useful in the field of room acoustics in order to provide right reverberation times. In most of the cases the behavior of the tested material is very similar to the one observed in typical mineral wool, namely, it increases the range of effectiveness of the resonators either in membrane resonators or in cavity resonators.

At this moment we have started two different evaluations. On the one hand we are investigating the reduction of noise generated by air-conditioned diffusers when their interior walls are covered with TBF. Preliminary results show decreases of the sound power level of the noise generated greater than 3 dB. On the other hand we have started an evaluation of the applicability of TBFs in the field of sound isolation. In this field, we are studding combinations of these materials with bituminous and elastomer materials conforming multilayer partitions.

Future tests will try also to pinpoint exactly the optimum composition, thickness, and density for specific applications in the field of room acoustics.

As an additional conclusion we have present an alternative representation of the absorption coefficient that allow to visualize easily the magnitude and the absolute or relative uncertainty.

## 5 REFERENCES

1 ISO 354: 1985, Acoustics – Measurement of sound absorption in a reverberation room
2 Jaime Ramis; Jesús Alba; F. Javier Redondo; Jose Bravo - An experimental study of devices for the control of reverberation by using textile material. 17 Th International Congress On Acoustics (2001), ICA 2001
3 J. Ramis; J. Alba; J. Bravo; F.J.Redondo -Absorption for the control of reverberation by using perforated gypsum. 17 Th International Congress On Acoustics (2001), ICA 2001
4 ISO 10534, Acoustics-Determination Of Sound Absorption Coefficient And Impedance Or Admittance By The Impedance Tube. Part I (1996): Standing Wave Ratio Method. Part II (1998): Transfer-Function Method."
5 A. Cops, J. Vanhaecht K. Leppens, Sound absorption in a Reverberation Room: Causes of Discrepancies on Measurement results. Applied Acoustics 46 (1995) 215-232.